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NOTE TO AUTHORS AND SUBSCRIBERS

With this issue *Soil Science* makes its first major format change since the journal was established in 1916. The space available for publication of papers remains the same, but the new format represents greater efficiency and economy in the use of space and in general problems of production. Authors are urged to consult carefully the new instructions for preparation of copy printed in this and all subsequent issues of the journal.

RETENTION AND FIXATION OF AMMONIA BY SOILS

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Most of the studies on retention and fixation of the ammonium ion by soils have been concerned primarily with the behavior of the ammonium ion applied as salts of strong acids. The exchange reactions of ammonia applied as anhydrous or aqua ammonia are not necessarily the same as those of other ammonium nitrogen carriers applied in the form of ammonium salts of strong acids. The ammonium ion is not retained effectively by acid soils because of the difficulty with which the adsorbed H^+ ions (in reality adsorbed aluminum ions) are replaced by monovalent cations. On the other hand, anhydrous ammonia by reacting directly with adsorbed hydronium and aluminum ions is strongly retained by acid soils.

Both NH_4^+ and K^+ ions are known to be fixed by clay minerals (3, 4, 17, 18). The amounts of NH_4^+ fixed from ammonium salts by most surface soils of the humid regions have been reported to be less than 1 me. per 100 g. of soil (1). The fixation of ammonia from anhydrous ammonia by soils may be expected to exceed the fixation of the NH_4^+ from neutral ammonium salts because ammonia may react directly with the soil organic matter to form organic nitrogen compounds that do not contain exchangeable NH_4^+. Mattson and Koutler-Andersson (8, 9, 10, 11, 12) showed that humus, leaf litter, and peats absorb large quantities of oxygen when these materials are treated with a base. This reaction, defined by the authors as autoxidation, was found to be related to the degree of oxidation of the organic matter. Upon treatment with NH_4OH, the litter, humus, and peat absorbed large amounts of oxygen and fixed simultaneously large amounts of ammonia which could not be recovered by digestion of the ammoniated sample with 4 *N* HCl or with 72 per cent H_2SO_4. Peats have also been shown to react with ammonia to form organic nitrogen compounds upon ammoniation at elevated temperatures and high pressures of ammonia (5, 16).

The object of this investigation was to study the retention and fixation of ammonia by soils with especial emphasis on the mechanism of fixation of ammonia into nonexchangeable forms.

MATERIALS AND METHODS

Representative New York mineral and muck soils covering a wide range in pH value, texture, and organic matter content were selected for this investigation. The organic matter content of the mineral soils was determined by the chromic acid method (15) and that of the organic soils by

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ignition. The pH determinations were made by means of the glass electrode (15).

The air-dry soil was placed in a glass bottle (2- to 20-liter capacity depending upon the amount of soil) and the anhydrous ammonia gas introduced into the bottle through Tygon tubing that extended well into the soil. During ammoniation the soil was kept in constant agitation by gently rolling the bottle. When the soil appeared to have been saturated with ammonia gas, the bottle was stoppered and the soil was allowed to stand overnight in contact with ammonia gas. The ammoniated soil was then transferred from the bottle into a shallow pan and placed under a hood. A portion of the ammoniated soil was immediately heated in an oven at 100°C. for 12 hours, cooled, placed in tightly stoppered bottles, and labeled "Ammoniated-heated at 100°C." Soils 1 to 4, inclusive, were subjected to this heat treatment. The remaining mineral soils and muck soils were subjected to a heat treatment that consisted of wetting the soils with distilled water to approximately 40 per cent moisture content, followed by drying the soils in an oven at 70°C. for 48 hours. After drying, the soils were removed, passed through a 2-mm. sieve, bottled, and labeled "Ammoniated-heated at 70°C." The remaining portion of the ammoniated soil in the pan was spread in a thin layer and allowed to aerate for a period of 1 week to remove the physically adsorbed ammonia.

Initially the control (untreated) soils were also subjected to the same heat treatment that was applied to the corresponding ammoniated soils, but this practice was abandoned when it was found that the amounts of total nitrogen, ammonia nitrogen, and nitrate nitrogen did not change significantly upon heating. Moreover, any effect of the heat treatment on the ammonia and nitrate nitrogen should not necessarily be the same in both the ammoniated and the control soils.

The total nitrogen content of the control and the ammoniated soils was determined by the Kjeldahl method with a provision for including nitrate nitrogen (14). The exchangeable NH_4^+ was determined by leaching a 20-g. sample of soil with 225 ml. of acidified (0.01 *N* HCl) 10 per cent NaCl solution, followed by distillation of the ammonia in the extracts from ammoniated soils or direct nesslerization of the extracts from the control soils (15). The nitrate nitrogen was determined by the phenoldisulfonic acid method (6). The exchangeable K^+ was determined by the flame photometer after extraction of a 20-g. sample of soil with 225 ml. of the acidified 10 per cent NaCl solution.

RESULTS AND DISCUSSION

The total uptake of ammonia and the amount of ammonia fixed by the soils, expressed as me. per 100 g. of soil and as per cent of the amount of ammonia sorbed, are shown in table 1. The organic matter content and the pH are also listed in table 1.

Retention of ammonia by soils

The ammonia-retention capacity of a soil, expressed as me. per 100 g. of soil, was calculated as the difference between the total nitrogen content of the ammoniated soil and that of the corresponding control (untreated) soil. The ammonia-retention capacity would be expected to be primarily a function of the exchangeable hydrogen content of the soil. This, however, was not found to be true, as shown by the amounts of ammonia sorbed by soils 2, 4, 5, 9, and 12. Although the original pH values of these soils were either equal to or higher than 6.5, these soils possessed fairly high ammonia-retention capacities. Soils 5 and 12 represent acid soils recently limed. Soil 2, however, was collected from a limestone area in western New York. Even at the high pH value (7.32) this soil sorbed 7.02 me. of ammonia per 100 g of soil, which is equivalent to 1965 pounds of ammonia nitrogen per 2 million pounds of soil.

As shown in table 1, pH values of most of the ammoniated-aerated soils were above 8. In all instances the uptake of ammonia by the mineral soils was found to decrease upon heating the ammoniated soil, presumably because of volatilization of ammonia held by hydrogen bonding and hydrolysis of NH_4^+ held by weakly acidic groups. As might be expected, the ammonia retention capacity of the three organic soils was found to be very high and related to the pH value of the muck samples. The two mucks with an original pH value of 4.90 sorbed considerably more ammonia than the Dryer muck at pH 6.10 even though the Dryer muck is intermediate in organic matter content. Inasmuch as the Anderson muck and the woody muck showed the same original pH values, it would be reasonable to expect that the Anderson muck, because of its higher organic matter content, would sorb more ammonia. A comparison of the data for these two

TABLE 1

Sorption and fixation of ammonia by soils

Soil Type	pH	Ammonia			pH of Original Soil	Organic Matter*
		Uptake*	Fixed*			
		me./100 g.	*me./100 g.*	%		%
1. Mardin silt loam						
ammoniated-aerated	8.42	17.7	3.62	20.5	4.70	4.15
ammoniated-heated at 100°C.	7.40	14.8	4.73	31.9		
2. Lima silt loam						
ammoniated-aerated	8.55	7.02	1.15	16.4	7.32	3.75
ammoniated-heated at 100°C.	8.10	6.42	2.14	33.3		
3. Sassafras f. sandy loam						
ammoniated-aerated	8.10	11.5	1.83	15.9	3.92	2.14
ammoniated-heated at 100°C.	7.24	9.28	2.51	27.1		
4. Sassafras f. sandy loam						
ammoniated-aerated	8.70	8.02	1.16	14.5	6.52	2.37
ammoniated-heated at 100°C.	7.90	8.00	3.23	40.4		
5. Dunkirk silt loam P364-O						
ammoniated-aerated	7.99	4.89	0.94	19.2	7.15	2.54
ammoniated-heated at 70°C.	7.73	4.07	1.03	25.3		
6. Dunkirk silt loam P364-H						
ammoniated-aerated	7.30	10.7	1.40	13.1	4.20	2.30
ammoniated-heated at 70°C.	6.50	9.14	1.77	19.3		
7. Mardin silt loam P365-O						
ammoniated-aerated	8.25	19.9	4.93	24.8	4.75	3.66
ammoniated-heated at 70°C.	7.25	15.8	4.41	27.9		
8. Mardin silt loam P365-H						
ammoniated-aerated	8.10	22.2	5.31	23.9	4.10	3.50
ammoniated-heated at 70°C.	7.05	17.9	4.76	26.6		
9. Honeoye silt loam P366-O						
ammoniated-aerated	8.08	7.83	1.34	17.2	6.62	3.15
ammoniated-heated at 70°C.	7.79	6.74	1.57	23.4		
10. Honeoye silt loam P366-H						
ammoniated-aerated	7.61	13.9	2.17	15.8	4.25	3.04
ammoniated-heated at 70°C.	6.81	11.9	2.77	23.2		
11. Gloucester loam P367-O						
ammoniated-aerated	8.40	13.3	3.34	25.1	5.80	4.90
ammoniated-heated at 70°C.	7.52	9.23	2.54	27.3		
12. Mardin silt loam C9P7						
ammoniated-aerated	8.70	7.50	2.01	27.8	7.25	3.18
13. Mardin silt loam S-14						
ammoniated-aerated	8.28	15.0	3.46	23.0	5.05	3.38
14. Mardin silt loam B-expt						
ammoniated-aerated	—	12.8	2.06	16.1	5.68	3.15
15. Anderson muck						
ammoniated-aerated	7.50	115.6	25.3	21.9	4.90	90.7
ammoniated-heated at 70°C.	7.50	171.5	65.0	37.9		
16. Dryer muck						
ammoniated-aerated	8.20	60.0	12.4	20.6	6.10	77.7
ammoniated-heated at 70°C.	7.39	71.2	25.3	35.6		
17. Woody muck						
ammoniated-aerated	8.20	126.3	22.0	17.4	4.90	63.2
ammoniated-heated at 70°C.	8.15	113.8	24.6	21.3		

* All values expressed on moisture-free basis. In the determination of moisture content, soils Nos. 1–4, inclusive, were dried at 100°C.; the remaining soils were dried at 70°C.

mucks, however, shows that the woody muck sorbed the greater amount of ammonia. The relatively large amounts of ammonia sorbed by the three light-textured soils 3, 4, and 11, as well as by soils with pH values above 7, indicates that interactions between ammonia and soil organic matter must play a significant role in the uptake of ammonia by surface soils.

Fixation of ammonia by soils

Ammonia-fixing capacity. As already pointed out, the difference between the total nitrogen content of the ammoniated soil and that of the corresponding control, Δ total N, was taken as the amount of ammonia sorbed by the soil. Similarly, the difference between the exchangeable ammonium nitrogen content of the ammoniated soil and that of the control, $\Delta(NH_4^+\text{-N})$, and the difference between the nitrate nitrogen content of the ammoniated soil and that of the control, Δ $(NO_3^-\text{-N})$, were also calculated. Inasmuch as the change in the nitrate nitrogen content of the soil upon ammoniation and drying was always found to be very small, no correction for nitrification was found necessary, and the amount of ammonia fixed by the soil was, therefore, calculated as follows:

Ammonia nitrogen fixed

$$= \Delta \text{ total N} - \Delta(NH_4^+\text{-N})$$

Since the exchangeable NH_4^+ was extracted under suction, the NaCl extracting solution was acidified to prevent loss of ammonia through volatilization. The addition of acid to the extracting solution also served to minimize the peptization of the soil organic matter. The NaCl rather than KCl solution, which has been often employed for this purpose (1, 2, 3, 4, 17), was selected for extraction inasmuch as the Na^+ ion is known to be more effective in replacing the adsorbed NH_4^+ and thus its use should lead to more conservative values for the fixation of NH_4^+ by the clay minerals. Obviously, the presence in the NaCl extract of any organic nitrogen compounds capable of liberating ammonia upon hydrolysis during the alkaline distillation of the NaCl extract would lead to low results for the amount of ammonia fixed by the soil. This possible source of error was checked by direct nesslerization of the NaCl soil extract. The two methods, distillation and nesslerization, gave identical results, so the amount of ammonia found in the NaCl extract was, therefore, taken to represent the exchangeable NH_4^+. In their studies of the ammonia-fixing capacity of soils, Allison *et al.* (1) first saturated the soil with NH_4^+ by leaching with NH_4Cl solution; they then removed the exchangeable NH_4^+ by leaching with KCl solution and measured the increase in total nitrogen content of the soil in comparison to that of the control soil, which was also subjected to leaching with the KCl solution. In this method, however, any differential loss by leaching of organic nitrogen compounds from the NH_4Cl-leached soil and the control soil would thus lead to low results for the amount of ammonia fixed by the soil.

The data (table 1) show that the soils that possessed the greatest capacity to sorb ammonia generally fixed the greatest amounts of ammonia. This is to be expected because the interlayer fixation of NH_4^+ by clay minerals should increase with increasing degree of saturation of the clay surface with NH_4^+ ions. Also the lower the pH and the higher the organic matter content of the soil, the greater should be the sorption and fixation of ammonia by the soil organic matter. At first the data appears not to support such a correlation because soil 6, the acid form of soil 5, did not fix much more ammonia than soil 5. There is also little difference between the amount of ammonia fixed by the original soil and that fixed by the corresponding acid soil if we compare soils 9 and 10. It must be remembered, however, that any apparent correlation between soil pH and amount of ammonia fixed should not be determined by pH *per se* but by the oxidation status of the soil organic matter (8). The acid soils in question were obtained by acid-leaching the soils with naturally high pH values. The acid treatment should not be expected to change the oxidation status of the soil organic matter and, hence, should have little effect upon the amount of ammonia fixed by the soil organic matter fraction.

In most instances heating the ammoniated soil decreased the ammonia-retention capacity but increased the fixation of ammonia. The amount of ammonia fixed, expressed as per cent of that sorbed, was also increased by heating even in soils that showed a decrease in the absolute amounts of ammonia fixed upon heating (soils 7, 8, and 11). This is not surprising since heating reduces the interlayer water, causes contraction of the crystal lattice, and should thus increase the NH_4^+ fixation by the clay minerals. At the same time

heating should also increase the fixation of ammonia by soil organic matter (16).

During the course of the work, the question arose as to whether the 225 ml. of the extracting solution used in extracting the exchangeable NH_4^+ was sufficient to remove the exchangeable NH_4^+ from a 20-g. soil sample. Several ammoniated soils were, therefore, chosen at random and subjected to five successive extractions using 225 ml. of the acidified 10 per cent NaCl solution for each extraction. The second extraction was found to remove only small additional amounts of NH_4^+ ranging from 0.1 to 0.5 me. per 100 g. of soil; the third and succeeding extractions recovered less than 0.1 me. of NH_4^+ per 100 g. of soil.

The large amounts of ammonia fixed by the three light-textured soils (soils 3, 4, and 11) and the three organic soils indicates that the greater part of the ammonia fixed by the mineral surface soils used in the present study is due to some reaction between ammonia and soil organic matter.

Fixation of ammonia after the H_2O_2 treatment. To assess more accurately the role played by the soil organic matter in the fixation of ammonia by soils, an attempt was made to determine the amount of ammonia fixed by soils before and after oxidation of the soil organic matter with hydrogen peroxide. If the H_2O_2 treatment is assumed to affect only the organic fraction of the soil, the amount of ammonia sorbed and fixed after the H_2O_2 treatment should be a function of the amount and type of clay.

Accordingly, the organic matter in 12 of the surface soils was destroyed by two successive treatments with 15 per cent H_2O_2. Each treatment consisted of adding H_2O_2 followed by digestion on a steamplate until evaporation reduced the suspension to a thin soil paste. The soil was then transferred to a centrifuge tube and washed two times with 70 ml. of 0.1 *N* HCl, followed by three washings with 0.002 *N* HCl in order to remove the soluble salts. The H^+-saturated soil was then transferred to a 250-ml. beaker, air-dried, weighed, ground to pass a 2-mm. sieve, and divided into two portions. The first portion was immediately bottled and used as H_2O_2-treated control soil, whereas the second was ammoniated according to the procedure already described for the original soils. After aeration at room temperature for 1 week, the ammoniated soils were bottled and stored in a refrigerator. The amounts of total nitrogen and exchangeable NH_4^+ in the ammoniated soils and the corresponding control H_2O_2-treated soils were determined according to the methods already described except that, in the determination of the exchangeable NH_4^+, a 2-g. sample of the soil in a 15-ml. centrifuge tube was extracted with five successive 10-ml. portions of the acidified 10 per cent NaCl solution. After each treatment with NaCl solution, the soil suspension was centrifuged and the clear NaCl extract was decanted.

Table 2 presents the data on the sorption and fixation of ammonia by these soils before and after treatment with H_2O_2. The data for the H_2O_2-treated soils are expressed in me. per 100 g. of original soil to permit direct evaluation of the contribution of the soil organic matter to the sorption and fixation of ammonia. In order to be consistent with the results presented in table 1, the data on the sorption and fixation of ammonia by the first five soils shown in table 2 are reported on an oven-dry basis. The values for the remaining soils are expressed on an air-dry basis.

A comparison of the data in table 2 for the H_2O_2-treated soils with that for the original soils shows that the removal of the organic matter markedly decreased the capacity of most soils to fix ammonia into nonexchangeable form. After the H_2O_2 treatment, the amount of ammonia fixed by the Sassafras fine sandy loam (soil 3) decreased from 1.83 to 1.46 me. per 100 g. of soil (a decrease of 20.2 per cent), whereas the amount of ammonia fixed by the other light-textured soil, the Gloucester loam (soil 11) decreased from 3.33 to 0.48 me. per 100 g. of soil (a decrease of 85.6 per cent). The Bath ch. silt loam (soil 18) still retained the capacity to fix 5.05 me. of ammonia per 100 g. of soil after destruction of the organic matter. The average decrease in the ammonia-fixing capacity after treatment with H_2O_2 for the soils shown in table 2 was found to be 48.5 per cent.

It has been tacitly assumed that the uptake and fixation values found after the peroxide treatment should represent that part of the sorption and fixation of ammonia by the original soil that may be attributed to the clay fraction. Three effects of H_2O_2 treatment, however, must be considered in the evaluation of the data presented in table 2: (*a*) the presence of soil organic matter is known to hinder the fixation of NH_4^+

TABLE 2

Sorption and fixation of ammonia by soils before and after treatment with hydrogen peroxide

Soil Type	Original Soil				H_2O_2-treated Soil			Decrease in Ammonia Fixation after H_2O_2 Treatment	
	Organic matter	pH	Ammonia		pH*	Ammonia			
			Uptake	Fixed		Uptake	Fixed		
	%		*me./100 g.*			*me./100 g.*		*me./100 g.*	%
2. Lima silt loam	3.75	7.32	7.02	1.15	5.49	5.00	0.75	0.40	34.8
3. Sassafras f. sandy loam	2.14	3.92	11.5	1.83	4.19	5.12	1.46	0.37	20.2
5. Dunkirk silt loam P364-O	2.54	7.15	4.89	0.94	4.15	6.00	0.36	0.58	61.7
7. Mardin silt loam P365-O	3.66	4.75	19.9	4.93	4.36	12.6	2.55	2.38	48.3
11. Gloucester loam P367-O	4.90	5.80	13.3	3.34	4.42	5.59	0.48	2.86	85.6
18. Bath ch. silt loam 53f	6.11	4.30	26.4	6.37	3.96	18.2	5.05	1.32	20.7
21. Erie ch. silt loam 14a	5.46	4.90	16.5	3.72	4.18	10.1	0.48	3.24	87.1
23. Ovid silt loam 28b	3.18	6.15	8.34	2.67	3.60	9.85	0.55	2.12	79.4
25. Valois ch. silt loam 17b	3.62	4.95	8.48	0.72	4.30	8.06	0.55	0.17	23.6
26. Honeoye silt loam 48c	2.94	6.35	4.66	0.69	3.70	6.39	0.62	0.07	10.1
27. Lansing silt loam 8a	4.07	5.00	10.9	2.47	3.61	8.99	0.53	1.94	78.5
28. Volusia silt loam 1a	5.32	5.72	11.8	2.40	3.49	11.9	1.62	0.78	32.5

* pH determinations were made using a 1:10 soil-water ratio.

(1), presumably by blocking the entrance of the ammonium ions between the clay plates, but the destruction of the soil organic matter with H_2O_2 should free these sites and thus increase the capacity of the clay to fix NH_4^+; (*b*) the H_2O_2-treated soils were H^+-saturated and, therefore, would be expected to retain and fix more ammonia; and (*c*) as shown by Barshad (4), the decrease in the particle size of the clay minerals, due to exfoliation upon H_2O_2 treatment, should increase both the uptake and fixation of NH_4^+.

In light of these effects, it is obvious that, if the capacity of a soil to fix ammonia resided solely in the clay fraction, the amount of ammonia fixed should have been increased by the H_2O_2 treatment. But this is not true, as may be seen from the data (table 2). The decreases in fixation of ammonia found upon treating the soils with H_2O_2 would lead to the conclusion that the organic matter of most surface soils possesses the capacity to fix ammonia into nonexchangeable form. Moreover, the average per cent decrease in the ammonia-fixing capacity of the soils, after H_2O_2 treatment, represents a very conservative or minimum value for the ammonia-fixing capacity of the soils that may be attributed to the soil organic matter.

Comparison of the fixation of potassium and ammonia by soils. Several workers have shown that K^+ is fixed by soils as much as NH_4^+ (2, 17). Clay minerals have been reported to fix larger amounts of K^+ than NH_4^+ (4, 7). The results of such studies have led to the conclusion that the fixation of K^+ and NH_4^+ in soils is accomplished by the same mechanism involving the clay fraction of the soil. A comparison of the capacities of surface soils to fix K^+ and ammonia should serve, therefore, as another means of evaluating the relative contributions of the clay and the organic matter fractions to the ammonia-fixation capacity of the soil. If autoxidation and simultaneous fixation of ammonia by the soil organic matter (8, 9, 10, 11, 12) is responsible for a significant portion of the fixation of ammonia by the surface soils, then the extent of ammonia fixation should exceed that of K^+ fixation by a given surface soil.

Accordingly the amounts of K^+ fixed by a number of soils for which data on the ammonia sorption and fixation were available were determined by adding standard KOH solution to the soils in amounts equivalent to the amounts of ammonia that were found to be taken up by the soils. The soils were then brought to 75 per cent moisture content with distilled water and, after drying, the amount of exchangeable K^+ was determined by the flame photometer after extraction with acidified 10 per cent NaCl solution as described earlier in this paper. The amount of K^+ fixed was calculated as the difference between the amount of K^+ added and the increase in the amount of exchangeable K^+ ef-

TABLE 3

Comparison of the fixation of potassium and ammonia by soils

Soil Type	pH of Original Soil	Organic Matter	Potassium Added	Potassium Fixation	Ammonia Fixation	Difference Between Potassium and Ammonia Fixation	
		%	*me./100 g.*	*me./100 g.*	*me./100 g.*	*me./100 g.*	%*
2. Lima silt loam	7.32	3.75	6.42	1.94	2.14	0.20	9.3
3. Sassafras f. sandy loam	3.92	2.14	9.28	0.18	2.51	2.33	92.8
4. Sassafras f. sandy loam	6.52	2.37	8.00	0.93	3.23	2.30	71.2
5. Dunkirk silt loam P364-O	7.15	2.54	4.07	0.90	1.03	0.13	12.6
6. Dunkirk silt loam P364-H	4.20	2.30	9.14	1.36	1.77	0.41	23.1
7. Mardin silt loam P365-O	4.75	3.66	15.8	3.08	4.41	1.33	30.1
8. Mardin silt loam P365-H	4.10	3.50	17.9	2.88	4.76	1.88	39.4
9. Honeoye silt loam P366-O	6.62	3.15	6.74	2.03	1.57	−0.46	−29.2
10. Honeoye silt loam P366-H	4.25	3.04	11.9	1.95	2.77	0.82	29.6
11. Gloucester loam P367-O	5.80	4.90	9.23	0.59	2.54	1.95	76.7
12. Mardin silt loam C9P7	7.25	3.18	7.50	0.75	2.01	1.26	62.6
18. Bath ch. silt loam	4.30	6.11	26.4	1.61	6.37	4.76	74.7
19. Bath ch. silt loam 5b	4.51	6.70	19.3	0.93	3.26	2.33	71.4
20. Mardin ch. silt loam 52e	4.42	5.95	21.4	1.03	4.97	3.94	79.2
21. Erie ch. silt loam 14a	4.90	5.46	16.5	1.03	3.72	2.69	72.3
22. Erie gr. silt loam 18c	6.48	5.82	8.79	0.21	1.26	1.05	83.3
24. Valois gr. silt loam 15a	6.80	5.80	6.24	0.30	1.57	1.27	80.8
25. Valois ch. silt loam 17b	4.95	3.62	8.48	0.27	0.72	0.45	62.5
26. Honeoye silt loam 48c	6.35	2.94	4.66	0.32	0.69	0.37	53.6
27. Lansing silt loam 8a	5.00	4.07	10.9	0.56	2.47	1.91	77.3
28. Volusia silt loam 1a	5.72	5.32	11.8	0.99	2.40	1.41	58.7
29. Langford ch. silt loam 12a	6.25	5.70	10.3	0.89	2.88	1.99	69.0
30. Langford gr. silt loam 20b	5.95	5.30	9.98	0.74	1.65	0.91	55.1
31. Kendaia silt loam 46d	6.72	4.25	4.96	1.60	0.84	−0.76	−90.4

* Expressed as per cent of the amount of ammonia fixed by the original soil.

fected by the KOH treatment. It was thought that the use of KOH rather than KCl, which has been often employed, should make the conditions for the fixation of K^+ more comparable to those under which the fixation of ammonia by these same soils was obtained.

The amounts of ammonia and K^+ fixed by the soils and the amount of K^+ added as KOH (equivalent to the ammonia uptake) are shown in table 3. The first 10 soils, shown in table 3, were dried overnight in the oven at 70°C. following the treatment with KOH. Hence, the amount of K^+ added was equivalent to the amount of ammonia sorbed by the ammoniated soil after heating, and all the data for these soils are expressed on an oven-dry basis. The remaining soils, following the treatment with KOH, were air-dried and all the data for these soils are expressed on an air-dry basis.

A comparison of the amounts of K^+ and ammonia fixed by the soils shows that, in most instances, ammonia was fixed in greater amounts and that the amount of ammonia fixed is in general related to the pH and the organic matter content of the soil. No such correlation, however, is apparent for the amount of K^+ fixed by these soils. The capacity of a soil to fix K^+ can, therefore, be associated only with the types and amounts of the clay minerals present in the soil.

It will be noted that Bath ch. silt loam (soil 18) and the Mardin ch. silt loam (soil 20) fixed four times as much ammonia as K^+. The low pH values and the large amounts of organic matter present in these soils were apparently favorable for the autoxidation of the soil organic matter and simultaneous fixation of ammonia in the ammoniated soils. A similar comparison of the amounts of ammonia and K^+ fixed by the three light-textured soils (soils 3, 4, and 11) further substantiates this conclusion. Because of their coarse texture, the fixation of ammonia by these soils can hardly be attributed to the clay fraction.

Indeed, the great difference between the amounts of ammonia and K^+ fixed by these soils can be explained only by postulating some reaction between the soil organic matter and ammonia. Soil 3 fixed thirteen times as much ammonia as K^+. Soil 4 with a relatively high pH value also showed this marked difference between the amounts of ammonia and K^+ fixed.

Two soils (soils 9 and 31) fixed more K^+ than ammonia. Because of the high pH value of these soils, the organic matter should have been already highly oxidized and, hence, ammoniation of these soils would not be expected to induce any appreciable autoxidation of the soil organic matter. Since the fixation of ammonia and K^+ by these soils may be attributed primarily to the clay fraction, the amounts of K^+ and ammonia fixed by them should, therefore, be of the same order of magnitude.

It can be seen from table 3 that the difference between the amounts of ammonia and potassium fixed, expressed as per cent of the amount of ammonia fixed by the soil varied greatly for the different soils. If it is assumed that both NH_4^+ and K^+ are fixed to the same extent by the clay minerals present in any given soil, then this value represents the percentage of the ammonia-fixing capacity of the original soil that can be attributed to the soil organic matter. But inasmuch as the clay minerals are known to fix more K^+ than NH_4^+, this percentage difference between the amounts of ammonia and potassium fixed by a given soil should represent a conservative or minimum value for the percentage of the total amount of ammonia fixed by the original soil that may be attributed to the soil organic matter.

Because the estimates of the percentage of the ammonia-fixing capacity of the soil that may be attributed to the soil organic matter based on the decrease in the extent of ammonia fixation upon H_2O_2 treatment or on the difference between the ammonia- and potassium-fixing capacities both lead to conservative or minimum values, the method giving the higher value for a given soil should more closely approximate the true ammonia-fixing capacity of the soil organic matter. When this is done for soils 18, 21, 25, 26, 27, and 28 (all of which were air-dried after ammoniation or the addition of KOH) it is seen that the amount of ammonia fixed by these soils that can be attributed to the soil organic matter, expressed as a per cent of the total amount of ammonia fixed by the soil, is 75, 87, 63, 54, 79, and 59 per cent, respectively. Inasmuch as these values are still conservative estimates, it may be concluded that at least one-half of the total amount of ammonia fixed by these six soils can be attributed to the soil organic matter.

SUMMARY

A study was made of the capacity of several representative New York soils to sorb and fix ammonia into nonexchangeable form. The capacity of the soil to sorb ammonia could be attributed to neutralization of the exchangeable hydronium and aluminum ions as well as to the formation of organic nitrogen compounds upon autoxidation of soil organic matter and simultaneous ammonia fixation. The highest amounts of ammonia were fixed by acid soils containing large amounts of organic matter. The organic soils fixed considerably more ammonia than the mineral soils. Heating an ammoniated soil reduced the ammonia-retention capacity but increased the ammonia-fixing capacity.

The destruction of the soil organic matter by oxidation with H_2O_2 markedly decreased the capacity of most soils to fix ammonia into nonexchangeable form. A comparison was also made of the amounts of ammonia and K^+ fixed by surface soils to verify the role played by the soil organic matter in the fixation of ammonia. Most of the soils were found to fix more ammonia than K^+. Of the two ions, the K^+ ion is known to be fixed more strongly by the clay minerals. Hence, the difference between the amounts of ammonia and potassium fixed by the soil, expressed as a per cent of the amount of fixed ammonia, represents a conservative estimate of the percentage of the ammonia-fixing capacity of the soil that can be attributed to the soil organic matter.

From the decrease in the extent of ammonia fixation upon H_2O_2 treatment and the difference between the ammonia- and potassium-fixing capacities of the soils, it may be concluded that at least 50 per cent of the amount of ammonia fixed by New York mineral surface soils was due to some reaction of ammonia with the soil organic matter.

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